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13. ABSTRACT (Maximum 200 words)

The formal description technique (FDT) Estelle (ISO 9074) was used for the advanced design and development of communication protocols. In particular, two protocols were studied: (1) Partial Order Connection POC (RFC1693), and (2) MIL-STD 188-220: Interoperability Standard for Digital Message Transfer Device Subsystems. POC has been used as the basis of two systems: REMDOR for Remote Multimedia Document Retrieval, and NETCICATS for Network Conscious Image Compression and Transmission. The Estelle specifications of MIL-STD 188-220 were approved as an official component of the MIL-STD in January 1998.

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Statement of Problem Studied

Motivated primarily by multimedia and authoring systems, this grant has investigate the use of the Estelle ISO International Standard formal description technique for the design and development of computer communication protocols.

One protocol investigated was the Partial Order Connection (POC) service/protocol introduced by the author in Internet RFC 1693 [Connolly94]. Unlike classic transport services that deliver objects either in the exact order transmitted or according to no particular order, POC provides a partial order service; that is, a service that requires some, but not all objects to be received in the order transmitted.

Two versions of POC were studied: reliable, which requires that all transmitted objects are eventually delivered [Marasli94], and unreliable, which permits the service to lose a subset of the objects [Diaz94]. In the unreliable version, objects are more finely categorized into one of three reliability classes depending on their temporal value.

POC was investigated for its practicality both as a substitute for TCP and as a general partial reliable protocol for applications that can tolerate periodic, yet controlled loss due to noise in the network service.

The second protocol investigated was MIL-STD 188-220: Interoperability Standard for Digital Message Transfer Device Subsystems. This protocol was studied in the context of CECOM's efforts to standardize version B, and to generate conformance test cases directly from Estelle specifications of the protocol derived at the University of Delaware's Protocol Engineering Laboratory.

Important Results

For evaluating POC, theoretical and practical protocol engineering results were the by-product of developing the application: NETCICATS (Network Conscious Image Compression and Transmission System). NETCICATS allowed us to study the

transmission of images that are reduced using progressive wavelet compression, and then transmitted either over low-bandwidth, battlefield networks, or over the Internet using POC (Partial Order Connection), TRUMP (Timed-Reliable Unordered Message Protocol), and other innovative transport protocols developed at Delaware's Protocol Engineering Laboratory.

The most important general result of this effort was the theoretical [Marasli96a, Marasli96b, Conrad96] and empirical demonstration [Iren98a, Iren98b, Steinder98] that for certain regions of network quality-of-service (i.e., packet loss rates, bandwidth, buffer resources at the sender/receiver, etc.), significant reductions can be achieved in the real-time transmission and verification of still images. Overall results have been published in [Amer99] and current publications are in progress based on the PhD dissertations by Sami Iren and Phillip Conrad.

The NETCICATS system is being further extended within the Army Research Laboratory ATIRP consortium in line with the Army's Soldier's Communications and Information Device (SCID). While ATIRP's goal is not to design or build such a device, it is to develop and/or exploit design ideas such as those in NETCICATS to make the underlying communications and information distribution technologies of a SCID device possible.

A further major accomplishment related to the NETCICATS research is the publication of a seminal tutorial on the Transport Layer in the journal *ACM Computing Surveys* [Iren99]. This article represents the foundation work of Sami Iren's PhD dissertation.

Using Estelle to investigate MIL-STD 188-220 [Li95, Burch95] resulted in several major technology transfer accomplishments.

(1) UD's Estelle specifications of MIL-STD 188-220B were included as an official part of the MIL-STD approved in January 1998. http://www.cis.udel.edu/~amer/CECOM

(2) The development of techniques and software for the automatic generation of conformance tests from UD's Estelle specifications resulted in the transfer of tests to CECOM, Ft. Monmouth, for use within its Digital Integrated Lab (DIL) Conformance Tester.

These Estelle formal specification results from the early years of the ARO contract provided a foundation for further 188-220 protocol investigation within the Army Research Lab ATIRP consortium.

While the official grant period of this ARO contract covered over five years (4/94 - 8/99), the original approved period was for three years. During the third year, financial

problems arose preventing the contract's funding. No-cost extensions were requested and approved to extend the contract for two years during which time ARO was able to provide some funds ($20K and $11.9K in 97 and 98, respectively) to support graduate students Sami Iren and Armando Caro.

Publications

1999

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Participating Scientific Personnel and Degrees

Professor Paul D. Amer, Principal Investigator

PhD Students

Phillip Conrad, ''Partial order and partial reliability transport service innovations in a multimedia application context'' (expected) 1999

Sami Iren, ''Network-conscious image compression,'' 1999

Mariusz Fecko, ''Timing and controllability issues in conformance testing of communication protocols,'' 1999

Rahmi Marasli, ''Performance analysis of partial-ordered/reliable transport services,'' 1997

MS Students

Mason Taube, ''Congestion control in a reliable, unordered transport protocol,'' (in progress)

Edward Golden, ''TRUMP: Timed-reliable, unordered message protocol,'' 1998

Gul Sezen, 1998

Greg Burch, 1997

Hao Li, 1997

BS Students

Armando Caro, BS Honors Degree w/ Distinction, ''ReMDoR 2.0: Remote multimedia document retrieval over partially-ordered, partially-reliable transport protocols,'' 1998

Inventions: none

Bibliography (see Publications)

Appendixes (none)